1978 -79
Research Paper PNW-245 -258

REGENERATION OF TREE SEEDLINGS AFTER CLEARCUTTING ON SOME UPPER-SLOPE HABITAT TYPES IN THE OREGON CASCADE RANGE

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Contents

Acknowledgment

This paper was developed from a thesis, "Stocking levels and seedling heights on clearcuts in relation to habitat type in the western Cascades of Oregon" (1976), written in partial fulfillment of the requirements for the degree of Master of Science, Oregon State University. The work was supported in part by a Mary McDonald Fellowship provided the author during his residence. Dr. William K. Ferrell, Professor of Forestry at Oregon State University, served as the major advisor and his assistance and advice are gratefully acknowledged. The Pacific Northwest Forest and Range Experiment Station provided technical advice during the conduct of the study and partial financial support for preparation of this report.

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REGENERATION OF TREE SEEDLINGS AFTER CLEARCUTTING ON SOME UPPER-SLOPE HABITAT TYPES IN THE OREGON CASCADE RANGE

Reference Abstract

Sullivan, Michael J.
1978. Regeneration of tree seedlings after clearcutting on some upper-slope habitat types in the Oregon Cascade Range. USDA For. Serv. Res. Pap. PNW-245, 17 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Describes survival and growth of tree seedling regeneration on five upper-slope habitats in the Oregon Cascade Range. Distinct differences exist between habitat types in both stocking potential and growth.

KEYWORDS: Regeneration (artificial), forest types, vegetation types, seedling growth, logging (-regeneration, Oregon (Cascade Range), *Abies amabilis*.

RESEARCH SUMMARY
Research Paper PNW-245
1978

Stocking characteristics and tree seedling growth to ages 5 and 7 were measured on 45 study units, representing five habitat types, established on clearcuts in the *Abies amabilis* Zone of the Western Cascades of Oregon. Units ranged from 6 to 30 acres (2.4 to 12 hectares) in size and from 7 to 15 years in age (time elapsed since harvest); they occupied a variety of slope aspects, inclinations, and topographic positions. Distinct differences exist between the habitat types in stocking potential after they are clearcut. The importance of individual tree species, the average height of tree seedlings at a given age, and some aspects of structure and composition of successional plant communities also vary substantially with habitat type. Results were used to formulate preliminary regeneration guidelines for the habitat types studied. Habitat type appears to be a potentially productive tool for foresters involved with regeneration management in the *Abies amabilis* Zone of the Western Cascades of Oregon.

Introduction

In the Western Cascades of Oregon, preliminary forest habitat types have only recently been identified (Dyrness et al. 1974); management guidelines based on them have yet to be developed.

In northern and portions of the central Rocky Mountains basic habitat type classifications have been largely completed and actual mapping of habitat types has been undertaken. Many silvicultural properties of forest land, including regeneration characteristics, have been shown to be well correlated with habitat type in the northern Rocky Mountains (Layser 1974). In the Pacific Northwest, however, the implementation of forest habitat type classification has not reached a comparable level of development. These forests fall within two major vegetation zones, the *Tsuga heterophylla* and the *Abies amabilis*,[1/] each defined by its dominant climax tree species. Greater obstacles to successful regeneration after timber harvest are generally encountered within the subalpine *Abies amabilis* Zone. Seedling environments are often harsh, and regeneration failures are not unusual after clearcut operations.

The purpose of this research was to relate regeneration success, as measured by stocking percentage and tree seedling growth, to habitat type on clearcuts in the *Abies amabilis* Zone of the Western Cascades of Oregon. For the *Abies amabilis* Zone, the results provide a first evaluation of the utility of habitat type classification in regeneration management and insight into regeneration problems associated with clearcuts. Information on early stages of plant succession on clearcuts is a byproduct.

[1/] Scientific names are from Hitchcock and Cronquist (1973).

Description of Study Area

LOCATION AND GENERAL CHARACTERISTICS

The study area encompasses 375 km^2 (150 mi^2) and is located within the Willamette National Forest approximately 72 km (45 mi) northeast of Eugene, Oregon (fig. 1). The area falls within the administrative jurisdiction of three Ranger Districts: Sweet Home, Blue River, and McKenzie Bridge. The H. J. Andrews Experimental Forest and the Wildcat Mountain Research Natural Area are also located within the study area.

TOPOGRAPHY AND GEOLOGY

The area is a region of mature landforms, possessing strongly dissected ridge and valley topography. Slopes are generally steep, but some areas at higher elevations are characterized by immature, rolling topography. Elevations range from 460 to 1 750 m (1,510 to 5,741 ft).

The study area lies within the major geologic province known as the Western Cascades and is characterized by massive accumulations of volcanic material of Eocene through Pliocene age (Peck et al. 1964, Swanson and James 1975). Exposed rock of the *Abies amabilis* Zone of the study area is typically composed of andesitic and basaltic flows, breccias, and lapillus tuffs. Surface deposits of volcanic tephras are not uncommon.

SOILS

Dyrness et al. (1974) reported that the soils at the higher elevations of the H. J. Andrews Forest (generally representative of the study area) could be grouped into three associations: andesitic soils which are weakly developed and have textures from loams to sandy loams; Ando-like soils derived from andesite and basalt and with loam to silt loam textures; and Brown Podzolic soils derived from andesite and basalt, and loamy in texture. Characteristically, these soils are well drained, moderately stony, and relatively shallow--1 to 3 m (3 to 9 ft).

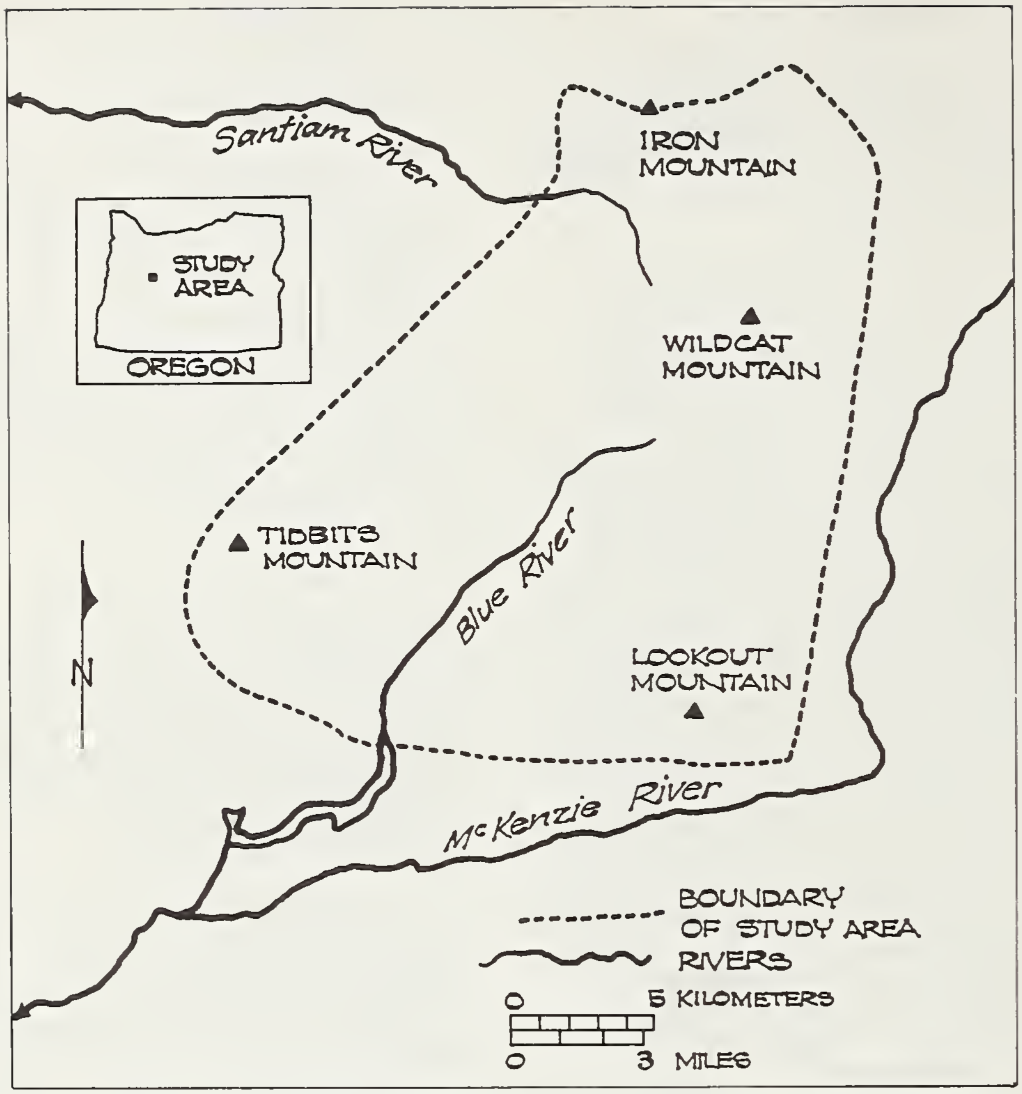

Figure 1.--Location of study area.

CLIMATE

The climate of the study area is characterized by relatively mild, wet winters and warm, dry summers. The climate at higher elevations (within the *Abies amabilis* Zone) is considerably more severe than that at lower elevations where most climatic data have been gathered. Within the *Abies amabilis* Zone the winter snowpack commonly ranges from 1 to 3 m in depth. Recently gathered data indicate that mean January air temperatures (under forest canopies 1 m above the forest floor) range from about -0.7^{o} to -2.4^{o}C (28^{o} to 31^{o}F), and mean July air temperatures range from about 14^{o} to 15.5^{o}C (57^{o} to 60^{o}F).[2/]

[2/] Unpublished data for 1973 and 1974, on file at the Forest Research Laboratory, Oregon State University, Corvallis.

Annual precipitation is estimated to range from 2 470 to 3 460 mm (98 to 136 in) at the higher elevations (Legard and Meyer 1973). Clear atmospheric conditions and low precipitation usually prevail during the summer.

VEGETATION

The study area lies within the Willamette ecologic province defined for the true fir-hemlock forests (Franklin 1965). *Abies amabilis* habitat types occur at the higher elevations of the study area and are generally found on the upper slopes of ridge systems and summits. Wildfires have been sufficiently frequent in the study area to prevent extensive development of forest stands to the full climax state. As a result, *Pseudotsuga menziesii* and *Abies procera*, distinctly seral species, are often the overstory dominants of forest stands within the *Abies amabilis* Zone. Tree species common to the *Abies amabilis* Zone of the study area are listed in table 1.

The *Abies amabilis/Achlys triphylla* association (Abam/Actr).

The *Abies amabilis/Tiarella unifoliata* association (Abam/Tiun).

The *Chamaecyparis nootkatensis/Oplopanax horridum* association (Chno/Opho).

Table 1--*Tree species of the* Abies amabilis *Zone of the study area*

Tree species	Importance[1/]
Abies amabilis (Pacific silver fir)	M
Abies procera (noble fir)	M
Pseudotsuga menziesii (Douglas-fir)	M
Tsuga heterophylla (western hemlock)	M
Tsuga mertensiana (mountain hemlock)	m
Pinus monticola (western white pine)	m
Chamaecyparis nootkatensis (Alaska-cedar)	m
Thuja plicata (western redcedar)	m
Abies grandis (grand fir)	m
Libocedrus decurrens (incense-cedar)	m
Picea engelmannii (Engelmann spruce)	i
Pinus contorta (lodgepole pine) var. *latifolia*	i
Pinus ponderosa (ponderosa pine)	i
Abies lasiocarpa (subalpine fir)	i

[1/] M = major importance, m = minor importance, i = insignificant.

Dyrness et al. (1974) identified and described seven *Abies amabilis* Zone climax communities (habitat types) occurring within the study area:

The *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax* association (Abam-Tsme/Xete).

The *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax* association (Abam/Vame/Xete).

The *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis* association (Abam/Rhma-Vaal/Coca).

The *Abies amabilis/Vaccinium alaskaense/Cornus canadensis* association (Abam/Vaal/Coca).

An eighth, previously undocumented, habitat type was recognized within the study area. *Abies amabilis* is the dominant climax tree species, and *Rhododendron macrophyllum* dominates the shrub layer. *Vaccinium alaskaense*, however, is either absent or insignificant, whereas *Vaccinium membranaceum* is typically present. For purposes of this analysis, this habitat type is designated the Abam/Rhma-Vame.

Cumulatively, these habitat types occupy a great deal of acreage in the northern Oregon and southern Washington Cascade Range. Several types, most notably the Abam/Vame/Xete, Abam/Vaal/Coca, and Abam/Actr are particularly widespread, both geographically and in total acreage (see, for example, Franklin 1966).

Methods

RECONNAISSANCE AND CHOICE OF STUDY UNITS

Before the study units were established, a detailed examination was made of Forest Service regeneration records to determine the general nature of clearcuts within the study area. Age, elevation, slope characteristics, site preparation, and regeneration histories were recorded for each clearcut thought likely to be located on *Abies amabilis* Zone habitat types. A field reconnaissance of these clearcuts, limited to those aged 7 to 15 years (harvested from 1960 to 1968) was subsequently undertaken. The limitation insured that each clearcut examined had ample time to regenerate; it also resulted in a satisfactory number of clearcuts for reconnaissance purposes.

A total of 121 clearcuts were examined in the field. A key developed by Dyrness et al. (1974) was used to classify habitat types. The habitat type of each clearcut was identified after examination of the vegetation of both the clearcut and surrounding, undisturbed stands thought to possess environments similar to that of the clearcut. Comparisons were based on factors such as similarity in slope, aspect, and landform.

Of the 121 clearcuts examined in the field, 52 were discarded from further consideration as unsuitable for study. Criteria for dismissal included: clearcut not on *Abies amabilis* habitat type; clearcut lacking uniformity on 5 or more acres because of broken topography, with major shifts in slope and/or aspect; clearcut heavily disturbed by roads or earth movements.

From the remaining clearcuts, 45 units, encompassing five habitat types, were chosen for detailed study. The habitat types and the number of units established in each type are:

Habitat type	Study units
Abam/Rhma-Vaal/Coca	11
Abam/Rhma-Vame	4
Abam/Actr	15
Abam/Vame/Xete	8
Abam-Tsme/Xete	7

In almost all cases the study units were not entire clearcut units but were portions thereof (from one-quarter to three-quarters of an entire clearcut and from 6 to 30 acres (2.4 to 12 ha) in size), on which habitat type and slope aspect and inclination as determined by compass and abney level were relatively uniform. Of the 45 study units, 42 were slash burned (93 percent), 36 were planted (to Douglas-fir, noble fir, or western white pine) at least once (80 percent), 10 were seeded (to Douglas-fir, noble fir, or western white pine) at least once (22 percent), and 41 of the units were planted and/or seeded at least once (91 percent). None of the units had been treated with herbicides or fertilizer. Environmental and treatment data for the individual areas are tabulated in appendix I of Sullivan.[3/]

COLLECTION OF DATA

A systematic sampling technique with a random element to determine specific locations for circular, 1-milacre (4.05-m^2) plots, was used. It entailed the use of parallel transects with fixed plot intervals (40 to 100 ft (12 to 30 m), depending on the study unit sampled) oriented perpendicularly to the slope. A random numbers table was used to position each plot a random number of paces perpendicularly right or left from the fixed plot interval along the transect line. This procedure established the center of each plot. The sampling intensity on individual study units ranged from 0.5 to 1.5 percent of the unit area.

The following data were collected on each milacre plot: (1) stocking condition (stocked or not stocked);

[3/] Sullivan, Michael James. 1976. Stocking levels and seedling heights on clearcuts in relation to habitat type in the western Cascades of Oregon. M.S. thesis, 81 p. (On file at Oreg. State Univ., Corvallis, Oreg.)

(2) number and species of trees present; (3) time of origin of each tree present, i.e., postharvest regeneration (originating after cutting) or advance regeneration (present before cutting); (4) height of each tree seedling at ages 5 and 7; (5) estimated percent canopy cover of shrub species and the herbs *Xerophyllum tenax* and *Pteridium aquilinum* (Daubenmire 1959).

Stocking determination was weighted by seedling age; a plot was stocked if it contained one of the following:

at least five 1-year-old trees,
at least three 2-year-old trees,
at least two 3-year-old trees, or
at least one 4-year-old tree.

Time of origin of trees present on sample plots was determined from the number of branch whorls and bud scale scars. Any tree older than the clearcut itself was classified as advance regeneration.

Tree seedling heights were determined as follows: the age of the seedling was estimated from a careful count of the number of branch whorls and bud scale scars; height was then measured at points corresponding to ages 5 and 7.

Cover percentage was estimated for all shrub species except trailing species, which typically contributed little to the total shrub cover of the units sampled. Because of time limitations, cover was estimated for only the two most important herbaceous species, *Xerophyllum tenax* and *Pteridium aquilinum*.

ANALYSIS OF DATA

Based on data collected in the field, several variables were derived as follows: (1) the stocking percentage of each study unit was the ratio of number of plots stocked to number of plots established multiplied by 100; (2) the number of trees per acre of each study unit was the total number of trees counted on all plots divided by the total number of plots established and multiplied by 1,000 to convert from a milacre to an acre basis; (3) the radiation index of each study unit was derived from measurements of slope aspect and inclination and tables prepared by Frank and Lee (1966); (4) the percent shrub cover of each study unit was the total cover percentages of each plot summed for all plots and divided by the total number of plots established.

Results and Discussion

STOCKING IN RELATION TO HABITAT TYPE

Differences in Stocking Among Habitat Types

Distinct differences exist among the stocking levels of the habitat types (table 2); an analysis-of-variance shows statistical significance at the 0.01-probability level. The Abam/Rhma-Vaal/Coca and Abam/Rhma-Vame habitat types show substantially higher mean stocking percentages than the other three types. For postharvest regeneration, this is supported by results of a multiple range test (table 3); differences between the Abam/Rhma-Vaal/Coca and Abam/Rhma-Vame habitat types are not significant but both differ significantly from the other three. Highly variable levels of advance stocking, possibly caused by variations in logging disturbance, slash treatment, and other site preparation activities, reduce the statistically significant differences (table 4).

Factors Affecting Differences in Stocking

Mean values for radiation index, elevation, and percent of shrub cover for each habitat type were compared with mean postharvest stocking percentage to see if differences in stocking were related to environment (table 5). Coefficient of determination (R^2) between mean stocking and several variables is:

Radiation index	0.825
Elevation	.604
Shrub cover	.047
Radiation index X elevation	.916

Radiation index and elevation are inversely related to stocking; a

Table 2--*Mean and median stocking percentages (all species combined) of clearcut study areas stratified by habitat type*

Habitat type[1/]	Postharvest stocking percentage		Advance stocking percentage	
	Mean	Median	Mean	Median
Abam/Rhma-Vaal/Coca	48.3	48.9	16.5	8.9
Abam/Rhma-Vame	44.1	41.6	14.0	5.4
Abam/Vame/Xete	20.1	19.1	2.0	1.3
Abam/Actr	18.7	17.1	2.7	2.3
Abam-Tsme/Xete	[2/]14.4	8.5	3.1	1.4

[1/] Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

[2/] Mean strongly influenced by one study unit with 50-percent stocking; the other sampling units of this habitat type had less than 16-percent stocking.

Table 3--*Significance of differences in postharvest mean stocking percentages between habitat types*[1/] [2/]

Habitat type	Abam/Rhma-Vaal/Coca	Abam/Rhma-Vame	Abam/Vame/Xete	Abam/Actr	Abam-Tsme/Xete
Abam/Rhma-Vaal/Coca	--	NS	**	**	**
Abam/Rhma-Vame		--	*	**	**
Abam/Vame/Xete			--	NS	NS
Abam/Actr				--	NS
Abam-Tsme/Xete					--

[1/] Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

[2/] * = significance at the 0.05-probability level; ** = significance at the 0.01-probability level; NS = nonsignificance.

Table 4--*Significance of differences in advance mean stocking percentages between habitat types*[1] [2]

Habitat type	Abam/Rhma-Vaal/Coca	Abam/Rhma-Vame	Abam/Vame/Xete	Abam/Actr	Abam-Tsme/Xete
Abam/Rhma-Vaal/Coca	--	NS	*	**	**
Abam/Rhma-Vame		--	NS	NS	NS
Abam/Vame/Xete			--	NS	NS
Abam/Actr				--	NS
Abam-Tsme/Xete					--

1/ Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

2/ * = significance at the 0.05-probability level; ** = significance at the 0.01-probability level; NS = nonsignificance.

Table 5--*Mean values of selected environmental parameters of clearcut study areas stratified by habitat type*

Habitat type[1]	Postharvest stocking	Radiation index	Shrub cover	Elevation	
	Percent		Percent	Meters	Feet
Abam/Rhma-Vaal/Coca	48.3	0.3789	36.3	1 161	3,810
Abam/Rhma-Vame	44.1	.3814	22.0	1 295	4,250
Abam/Vame/Xete	20.1	.4391	25.4	1 303	4,275
Abam/Actr	18.7	.4982	44.5	1 300	4,267
Abam-Tsme/Xete	14.4	.4621	10.9	1 433	4,700

1/ Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

strong inverse correlation also exists between the interaction product of elevation and radiation index and of stocking.

These results suggest several hypotheses. The inverse correlation between radiation index and stocking could be the result of higher radiation levels during the warm season reducing seedling survival. The negative effect of elevation on stocking could be the result of several interactions. For example, the frequency of freeze-thaw cycles may increase with increasing elevation and be reflected in an increase in seedling mortality caused by frost heave.

The results of these analyses of correlation between environmental values and stocking values for habitat types are largely confirmed by an independent multiple regression analysis. In this stepwise procedure, stocking percent on each study area was the dependent variable; radiation index, elevation, slope percent, shrub cover, years since cutting, and number of regeneration operations were the independent variables. The first two factors selected were radiation index and elevation; the equation--stocking percent = 174.7 - 0.022 (elevation) - 120.1 (radiation index)--had an R of 0.72. Addition of the other four independent variables only increased the R to 0.75.

These few variables can, at best, provide only partial explanations of the mean stocking percent differences between habitat types. Too many other factors and interactions between factors are not accounted for in this study. Furthermore, the importance of environmental and treatment factors varies with habitat type (table 6); some factors have very low correlations with stocking on all habitat types (e.g., shrub cover), but other factors are highly correlated with stocking percent on one or two habitat types. The results of the analyses do suggest that the superior stocking levels on Abam/Rhma-Vaal/Coca and Abam/Rhma-Vame habitat types very possibly result from more favorable seedling environments (table 5).

Stocking Percentages of Individual Tree Species

Douglas-fir stocking is superior to that of noble fir on the Abam/Rhma-Vaal/Coca habitat type, whereas noble fir stocking is far superior to that of Douglas-fir on the Abam/Rhma-Vame, Abam/Vame/Xete, and Abam-Tsme/Xete habitat types (table 7). When subjected to paired t-tests, the differences in the stocking percentages of the two species were found to be significant on the Abam-Tsme/Xete habitat type ($p<0.05$) and on the Abam/Vame/Xete and Abam/Rhma-Vame habitat types ($0<0.01$).

The superiority of noble fir stocking over that of Douglas-fir on the Abam/Vame/Xete, Abam-Tsme/Xete, and Abam/Rhma-Vame habitat types appears to be a result of better survival in seedling environments experienced on these sites. The drastic differences in species stocking on these habitat types cannot be attributed to a lack of Douglas-fir seed for natural regeneration; stands adjacent to most of the study units of these habitat types contain an adequate seed source of both Douglas-fir and noble fir. Planting or seeding operations also fail to explain the superiority of noble fir. Records (table 8) indicate that Douglas-fir was planted or seeded as frequently as was noble fir on units in the Abam/Vame/Xete, Abam-Tsme/Xete, and Abam/Rhma-Vame habitat types and in similar numbers (discussed by Sullivan, page 44 of his thesis; see footnote 3, page 4); therefore, it appears that noble fir seedlings are simply much more able to establish themselves than are seedlings of Douglas-fir on those habitat types.

Differences Between Habitat Types in Regeneration Density

Density of tree seedlings on each habitat type (mean number of trees per acre) is shown for individual species and for all species combined in table 9. Based on an analysis of variance, differences between habitat types in both total postharvest and total advance trees are statistically significant at the 0.01- and 0.05-probability levels, respectively.

In considering mean per-acre values for all regeneration combined on the Abam/Vame/Xete, Abam-Tsme/Xete, and Abam/Actr habitat types, the reader should be aware that the trees in general are poorly distributed and that a few study units have high values which strongly influence the means (table 10).

Table 6--*Coefficient of determination* (R^2) *between postharvest stocking and several environmental and treatment variables*

Habitat type[1/]	R^2 values between stocking and:				
	Radiation index	Shrub cover[2/]	Elevation	Number of regeneration operations conducted[3/]	Age of study units
Abam/Rhma-Vaal/Coca and Abam/Rhma-Vame combined	0.006	0.004	0.010	0.040	0.165
Abam/Actr	.118	.108	.524	.620	.229
Abam/Vame/Xete	.479	.123	.011	.039	.194
Abam-Tsme/Xete	.860	.058	.041	.012	.024

[1/] Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

[2/] For the Abam-Tsme/Xete habitat type only: shrub cover plus cover of *Xerophyllum tenax* and *Pteridium aquilinum.*

[3/] Number of times the study site was planted and/or seeded.

Table 7--*Mean postharvest stocking of Douglas-fir, noble fir, and all species combined*

Habitat type[1/]	All species	Douglas-fir	Noble fir
		Percent	
Abam/Rhma-Vaal/Coca	48.3	31.8	16.7
Abam/Actr	18.7	8.8	8.7
Abam/Vame/Xete	20.1	5.6	13.2
Abam/Rhma-Vame	44.1	4.8	32.1
Abam-Tsme/Xete	14.4	.2	13.6

[1/] Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

Table 8--*Regeneration histories of study units*

Habitat type[1/]	Planted		Seeded	
	Number	Species	Number	Species
Abam/Rhma-Vaal/Coca	6	Douglas-fir and noble fir	2	Douglas-fir and noble fir
	3	Douglas-fir	2	Douglas-fir
Abam/Actr	12	Douglas-fir and noble fir	2	Douglas-fir
	3	Douglas-fir		
Abam/Rhma-Vame	2	Douglas-fir and noble fir	0	--
Abam/Vame/Xete	3	Douglas-fir and noble fir	3	Douglas-fir and noble fir
	2	Douglas-fir		
Abam-Tsme/Xete	4	Douglas-fir and noble fir	1	Douglas-fir
	1	Noble fir		

[1/] Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

Table 9--*Mean number of trees per acre by habitat type, species,*[1/] *and time of regeneration*

Habitat type[1/]	Total	Douglas fir	Noble fir	Pacific silver fir	Western hemlock	Mountain hemlock	Western white pine	Western redcedar	Grand fir	Lodgepole pine	Incense-cedar
					POSTHARVEST TREES						
Abam/Rhma-Vaal/Coca	1,080	626	267	115	52	--	18	--	--	--	2
Abam/Rhma-Vame	962	52	720	100	--	72	14	--	--	4	--
Abam/Vame/Xete	292	56	182	44	2	--	2	--	4	--	2
Abam-Tsme/Xete	291	2	263	8	--	18	--	--	--	--	--
Abam/Actr	272	102	114	29	16	--	5	--	6	--	--
					ADVANCE TREES						
Abam/Rhma-Vaal/Coca	402	--	--	368	25	2	--	5	2	--	--
Abam/Rhma-Vame	437	--	20	403	9	--	--	--	5	--	--
Abam/Vame/Xete	36	--	--	36	--	--	--	--	--	--	--
Abam-Tsme/Xete	35	--	11	18	--	6	--	--	--	--	--
Abam/Actr	42	--	5	30	7	--	--	--	--	--	--

[1/] Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax;* Abam/Actr = *Abies amabilis/Achlys triphylla.*

Table 10--*Trees per acre--study unit variability*

Habitat type[1/]	Mean number of trees per acre (combined total)	Study units		
		Number	With less than 300 trees per acre	With less than 100 trees per acre
Abam/Rhma-Vaal/Coca	1,482	11	0	0
Abam/Rhma-Vame	1,399	4	0	0
Abam/Vame/Xete[2/]	328	8	4	3
Abam-Tsme/Xete[2/]	326	7	6	2
Abam/Actr[2/]	314	15	10	5

[1/] Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax;* Abam/Actr = *Abies amabilis/Achlys triphylla.*

[2/] In general, trees are poorly distributed and a few study units have high values which strongly influences the means.

SEEDLING GROWTH IN RELATION TO HABITAT TYPE

In the study area, growth rates of tree seedlings are generally slow on clearcuts within the *Abies amabilis* Zone. Temperature regimes during the short growing season are considerably less than optimum (Zobel et al. 1974). Another environmental restriction on growth may be damage caused by heavy winter snowpack (Williams 1966); snowbreak can reduce the growth rates of seedlings and saplings on these habitats.

Although heights of all postharvest seedlings on the plots were determined for ages 5 and 7, only two tree species, Douglas-fir and noble fir, were sampled often enough to permit a meaningful statistical analysis of seedling growth.

Mean heights at ages 5 and 7 are clearly greatest for both Douglas-fir and noble fir on the Abam/Actr habitat type and least on the Abam/Rhma-Vame habitat type (table 11). Limited data on heights attained by Pacific silver fir seedlings in relation to habitat type suggest that they follow a similar pattern. One possible explanation of the superior height growth achieved by seedlings on clearcuts of the Abam/Actr habitat type is that southerly exposures where Abam/Actr often occurs have higher radiation loads than other habitat types, resulting in more favorable thermal environments for growth.

An analysis of variance showed the differences in mean heights of Douglas-fir on different habitat types to be significant at the 0.01-probability level for both ages. A statistical difference (at 0.01 level) in noble fir heights exists only at age 7.

Douglas-fir seedling growth clearly exceeded that of noble fir on study areas in the Abam/Vame/Xete and Abam/Actr habitat types. On the Abam/Rhma-Vame and Abam/Rhma-Vaal/Coca types there was little difference in average height of the two species, although noble fir was slightly greater than Douglas-fir. Limited height measurements on Pacific silver fir seedlings indicate that, on any given habitat type, Pacific silver fir mean height is roughly half that of Douglas-fir and noble fir seedlings of equivalent age. Overall, these data suggest that the three species rank Douglas-fir

Table 11--*Mean height*[1/] *of Douglas-fir and noble fir seedlings at ages 5 and 7 on five habitat types*

Habitat type[2/]	Douglas-fir age (years)		Noble fir age (years)	
	5	7	5	7
		Centimeters		
Abam/Rhma-Vame	16.4	3/	18.6	32.3
Abam/Rhma-Vaal/Coca	21.1	36.4	23.1	37.6
Abam-Tsme/Xete	3/	3/	20.5	34.3
Abam/Vame/Xete	31.5	49.9	20.0	32.3
Abam/Actr	35.2	62.9	26.1	51.6

1/ Based on 485 Douglas-fir seedlings and 784 noble fir seedlings.

2/ Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam/Actr = *Abies amabilis/Achlys triphylla.*

3/ Deleted because of small numbers of observations.

≥ noble fir ≥ Pacific silver fir in height attained at ages 5 and 7--a ranking similar to Williams' (1968) ranking for open-grown seedlings and saplings on upper-slope clearcuts.

PLANT COMMUNITY DEVELOPMENT ON UPPER-SLOPE CLEARCUTS

Data on coverage and frequency of shrubs and selected herbs make possible some limited characterizations of plant communities 7 to 15 years after clearcutting on these upper-slope habitat types (table 12). For purposes of discussion, residual species are defined as those with at least 50-percent constancy in mature forest stands on a particular habitat type, whereas invader species are those with less than 50-percent constancy. The data for mature stand constancies are those of Dyrness et al. (1974).

Abam-Tsme/Xete Habitat Type

Successional communities on clearcuts of this habitat type are strongly dominated by herbs--mainly *Xerophyllum tenax;* shrubs will apparently not dominate these communities prior to canopy closure. Shrub cover on the seven study units averages 10.9 percent, whereas the cover of *Xerophyllum tenax* averages 32.4 percent. *Vaccinium membranaceum* averages 2.1-percent cover and is the only residual shrub of any importance on the study units. Although *Xerophyllum tenax* typically dominates on this site, its cover may be less than that existing before logging.[4/]

The major invading species on most study units 7 to 10 years after disturbance are a variety of grasses and sedges which tend to occupy the interstices between clumps of *Xerophyllum tenax.* The most important invading shrub is *Ribes viscosissimum* var. *halli*, which averages 2.9-percent cover. Other shrub invaders are *Rubus leucodermis* and *Ceanothus velutinus*,

4/ *Xerophyllum tenax* coverage averaged 64 percent in undisturbed forest stands on the Abam-Tsme/Xete habitat type studies by Dyrness et al. (1974).

Table 12--*Mean cover and frequency of selected shrub and herbaceous species*

(In percent)

Layer and species	Habitat type[1]									
	Abam/Rhma-Vaal/Coca		Abam/Rhma-Vame		Abam/Actr		Abam/Vame/Xete		Abam-Tsme/Xete	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
Tall shrub layer:										
Acer circinatum	0.4	2	0	0	4.9	12	0.5	2	0.1	2/
Acer glabrum	0	0	0	0	2/	2/	0	0	0	0
Alnus sinuata	0	0	0	0	.3	1	.1	1	0	2/
Amelanchier alnifolia var. *semiintegrifolia*	0	2/	0	0	2/	2/	0	2/	.1	2
Arctostaphylos columbiana	.5	2	0.8	4	.1	1	0	0	0	0
Castanopsis chrysophylla	.4	2	0	1	2/	2/	0	0	.3	2/
Ceanothus velutinus	4.3	14	.7	5	15.4	29	3.6	22	1.1	10
Holodiscus discolor	2/	2/	0	0	.2	1	.5	2/	0	0
Pachistima myrsinites	.4	5	.4	2	1.2	12	.8	8	.5	7
Prunus emarginata	.4	1	0	0	2.6	13	2.1	13	.1	1
Rhododendron macrophyllum	13.3	49	14.6	52	.1	1	0	0	0	0
Ribes lacustre	0	0	.3	3	.7	5	.2	2/	2/	2/
Ribes lobbi	0	2/	0	0	.8	6	.2	1	0	0
Ribes viscosissimum var. *halli*	.7	4	.2	2	6.1	27	6.3	34	2.9	11
Rubus leucodermis	2/	2/	2/	1	2/	2/	.1	1	1.8	1
Rubus parviflorus	.2	1	.1	3	6.4	31	4.4	33	.2	12
Rubus spectabilis	0	0	0	0	2/	2/	0	0	0	0
Salix lasiandra	0	0	0	0	0	2/	0	0	0	0
Salix scouleriana	0	0	0	0	2/	2/	.1	2/	0	0
Salix sitchensis	.2	1	0	0	.1	1	.1	1	0	0
Sambucus cerulea	2/	2/	0	0	.1	2/	0	0	0	0
Sambucus racemosa	.4	1	.2	2	1.6	10	.5	4	.3	1
Vaccinium alaskaense	11.6	53	.3	3	.9	6	0	0	0	0
Vaccinium membranaceum	2.0	21	4.3	43	1.7	17	4.2	45	2.1	35
Vaccinium parvifolium	0	2/	0	0	0	0	0	0	0	0
Vaccinium scoparium	0	0	0	0	0	0	0	0	2/	2/
Low shrub layer:										
Arctostaphylos nevadensis	0	0	0	0	0	2/	0	1	.6	4
Berberis nervosa	.8	21	2/	1	.1	2	0	2/	0	0
Juniperus communis	0	0	0	0	0	0	0	0	.2	1
Rosa gymnocarpa	.5	3	.1	1	.4	4	.4	5	.2	3
Symphoricarpos mollis var. *hesperius*	.2	1	.1	1	.6	3	1.3	6	.4	4
Total shrub cover	36.3		22.2		44.3		25.4		10.9	
Herb layer:										
Pteridium aquilinum	.7	6	1.0	8	10.2	41	11.3	55	1.6	11
Xerophyllum tenax	5.9	32	20.7	75	.3	3	20.4	64	32.4	78

1/ Abam/Rhma-Vaal/Coca = *Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cornus canadensis;* Abam/Rhma-Vame = *Abies amabilis/Rhododendron macrophyllum-Vaccinium membranaceum;* Abam/Actr = *Abies amabilis/Achlys triphylla;* Abam/Vame/Xete = *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax;* Abam-Tsme/Xete = *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax.*

2/ Less than 0.5 percent frequency or less than 0.05 percent cover.

although the *Ceanothus* occurs infrequently and is generally of low vigor.

Abam/Vame/Xete Habitat Type

The plant communities which developed after logging on this habitat type are generally herb dominated, but the shrub cover of 25.4 percent is greater than on the Abam-Tsme/Xete habitat type. *Xerophyllum tenax* averages 20.4-percent cover and is of major importance in the herbaceous layer, although its cover may be substantially less than that which existed before logging.[5] The abundance of *Pteridium aquilinum*, an invader species which averages 11.3-percent cover, is greater on the study units of Abam/Vame/Xete than on the study units of Abam-Tsme/Xete.

Vaccinium membranaceum is the dominant residual shrub, averaging 4.2-percent cover. *Ribes viscosissimum* var. *halli* (6.3-percent mean cover) and *Rubus parviflorus* (4.4-percent mean cover) are the most important invading shrubs, followed by *Ceanothus velutinus* and *Prunus emarginata*. Shrub development seems greater on study units on warmer aspects, whereas on cooler aspects *Xerophyllum tenax* and other herbaceous species are so well developed that development of a shrub-dominated community seems unlikely.

5/ *Xerophyllum tenax* averaged 39-percent cover in undisturbed forest stands of the Abam/Vame/Xete habitat type sampled by Dyrness et al. (1974).

Abam/Rhma-Vame Habitat Type

Plant communities on the four study units of this habitat type are poorly developed. Much mineral soil remains exposed and is unoccupied by vegetative cover, even though 10 to 15 years have elapsed since logging. Herbaceous development is limited, with the exception of *Xerophyllum tenax*, which averages 20.7-percent cover. *Rhododendron macrophyllum* (14.6-percent mean cover) and *Vaccinium membranaceum* (4.3-percent mean cover), two residual species, dominate the shrub layers of these communities. All invading shrub species are of minor importance.

Abam/Rhma-Vaal/Coca Habitat Type

Two residual species, *Rhododendron macrophyllum* and *Vaccinium alaskaense*, dominate the modest shrub layers (average 36.3-percent cover) of communities on the 11 study units established in this habitat type (table 12). The only notable invading shrub is *Ceanothus velutinus*, which occurs on slightly over half the units; *Ceanothus* is dominant on one unit and codominant on another but of little importance on the remainder.

Cornus canadensis is generally prominent in the herbaceous layer of these plant communities, as is *Xerophyllum tenax*. *Epilobium* species are important and generally abundant invading herbs.

The dominant roles played by *Rhododendron macrophyllum*, *Vaccinium alaskaense*, *Xerophyllum tenax*; and *Cornus canadensis* in these early successional communities suggest that the understory vegetation of mature forests on this habitat type tends to reconstitute itself fairly rapidly after disturbance.

Abam/Actr Habitat Type

The mean shrub cover on study units of this habitat type (44.5 percent) is the greatest encountered on the five habitat types (table 12). This is surprising since undisturbed stands on this habitat type often have poorly developed shrub layers. The mean shrub cover includes two study units with dense, vigorous stands of *Ceanothus velutinus*; even if these two units are excluded, shrub cover averages 38 percent.

Four shrub species, including three invaders, are dominants. *Ceanothus velutinus*, *Rubus parviflorus*, and *Ribes viscosissimum* var. *halli* (the invaders) average 15.4-, 6.4-, and 6.1-percent cover, respectively, and the residual *Acer circinatum* averages 4.9-percent cover. Almost without exception, one of these four species is the dominant shrub on any given study unit. The constancy of two invading species, *Prunus emarginata* and *Sambucus racemosa*, and two residual species, *Vaccinium membranaceum* and *Pachistima myrsinites*, is relatively high, but these species are of secondary importance.

Herbaceous vegetation is well developed on many of the clearcut units studied. *Pteridium aquilinum* is often abundant (10.2-percent mean cover) and is the dominant herb on many study units. Residual species usually present include *Smilacina stellata*, *Achlys triphylla*, *Asarum caudatum*, *Cornus canadensis*, and *Tiarella unifoliata*. *Epilobium* species are abundant invaders on some study units of this habitat type.

A consistent successional sequence is not apparent. Communities on some Abam/Actr units are already shrub dominated at 7 to 15 years; others are approaching a shrub stage; and still others, which possess well-developed herb layers and poorly developed shrub layers, never will pass through a shrub-dominated phase of development.

Silvicultural Implications

The results of this study indicate that differences exist between habitat types in total stocking potential, stocking potential of individual species, height growth of tree seedlings, and development of vegetation after clearcutting. Different silvicultural approaches may, therefore, be desirable or even necessary on different habitat types for successful regeneration. Of particular importance is the fact that many clearcuts in the *Abies amabilis* Zone of the Western Cascades of Oregon encompass two or more habitat types. Consequently, different portions (habitat types) of the same clearcut may need to be managed differently to attain maximum success in regeneration. Based on the results of this research, the following preliminary regeneration guidelines are proposed.

Abam/Rhma-Vaal/Coca Habitat Type

The clearcut system seems well suited to regeneration of forest stands on the Abam/Rhma-Vaal/Coca habitat type. This type possesses the most moderate seedling environment of all the types studied; adequate regeneration is usually achieved after clearcutting. Douglas-fir and noble fir are both suitable species for artificial regeneration. Generally, the most acute problem on clearcuts on this habitat type seems to be slow growth rates of seedlings. Low solar energy inputs during the growing season and competition between tree seedlings and shrubs may restrict seedling growth on this habitat type.

Abam/Rhma-Vame Habitat Type

This habitat type appears to behave like the Abam/Rhma-Vaal/Coca habitat type after clearcutting. Adequate regeneration is readily obtained, but established tree seedlings grow very slowly. Consequently, they are susceptible to damage from biotic agents (mammals, primarily) and damage from debris and heavy snowpack accumulations for long periods. Better stocking-level control and, perhaps, fertilization of tree seedlings may shorten this period of susceptibility.

Abam/Actr Habitat Type

This habitat type typically occurs on south- and west-facing slopes. High summer radiation, greater frequency of frost heave, rodent damage, and competition from shrubs and herbs all contribute to the poor stocking levels often observed on clearcuts on this habitat type.

The shelterwood system would seem to be an appropriate silvicultural system for stands on the Abam/Actr habitat type, provided such stands are not positioned on ridgetops or on overly steep slopes. Williamson (1973) reported that shelterwood harvesting of upper-slope Douglas-fir and mixed-conifer stands on severe sites in the Oregon Cascades is feasible and results in increased seedling establishment. If the clearcut system is used, cutting units should be kept small to ameliorate the seedling environment, and care should be taken to protect advance regeneration. Broadcast slash burning on this habitat type probably increases the severity of the seedling environment and destroys advance regeneration.

Brush development can be vigorous on some sites. When regeneration is established promptly, tree seedlings successfully compete with shrubs. On moister phases of this habitat type, dense herbaceous vegetation often develops rapidly after logging and seems to retain dominance for extended periods. This again emphasizes the need for rapid seedling establishment since the herbaceous vegetation is difficult to control once it dominates the site.

In summary, cutting systems which moderate the seedling environment and lead to prompt establishment of the new stand are particularly important on this habitat type. Seedling growth after establishment will be good.

Abam/Vame Xete Habitat Type

Although regeneration problems often follow clearcutting on this habitat type, no alternative even-aged silvicultural system may be suitable. The ridgetop or near ridgetop location of Abam/Vame/Xete sites may preclude shelterwood cutting because of a high risk of windthrow in the residual overstory. Clearcuts should generally be kept small to minimize environmental extremes and enhance natural regeneration. Large-scale site preparation methods should be avoided if possible because of potential damage to advance regeneration. Results of this study indicate that noble fir should be favored over Douglas-fir in planting operations. Brush competition is not a major regeneration problem on this habitat type.

Abam-Tsme/Xete Habitat Type

Clearcut study areas on this habitat type rarely had adequate stocking; in fact, regeneration was often nearly nonexistent. Shelterwood cutting, which would provide a less severe seedling environment, may be inappropriate because of potential losses of leave trees to wind and sun scald on the exposed ridgetops. Selection of uneven-aged management systems may also be limited by these and other factors such as steep slopes. Given all the constraints on this habitat type--low productivity (average Douglas-fir site quality V), severe regeneration problems, and limitations on suitable cutting methods--forest managers should consider a no-harvest option.

Preservation of advance regeneration is critical when the decision is made to cut on this habitat type, particularly when clearcutting is to be used. This will provide insurance if, as frequently is the case, postlogging regeneration is only slowly established. It is preferable that mineral seed beds and seedling planting sites be created by site preparation activities other than burning. Douglas-fir should not be planted on this habitat type. Since seedling establishment and subsequent growth are slow, rotations on this habitat type may have to be considerably longer than rotations envisioned for forests at lower elevations in the *Abies amabilis* Zone.

Conclusions

The results of this study demonstrate the utility of habitat types in regeneration management in the *Abies amabilis* Zone of the study area and suggest additional research, to include analyses of regeneration behavior, site index, occurrence and virulence of tree diseases, and possibly other silvicultural aspects of the whole series of Western Cascades habitat types.

Literature Cited

Cronquist, C. Leo, and Arthur Cronquist. 1973. Flora of the Pacific Northwest. 730 p. Univ. Wash. Press, Seattle.

Daubenmire, R. F. 1959. A canopy coverage method of vegetational analysis. Northwest Sci. 33(1):43-64.

Dyrness, C. T., Jerry F. Franklin, and W. H. Moir. 1974. A preliminary classification of forest communities in the central portion of the western Cascades in Oregon. Coniferous For. Biome Bull. 4, 123 p.

Frank, Earnest C., and Richard Lee. 1966. Potential solar beam irradiation on slopes: tables for 30° to 50° latitude. USDA For. Serv. Res. Pap. RM-18, 116 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Franklin, Jerry F. 1965. Tentative ecological provinces within the true fir-hemlock forest areas of the Pacific Northwest. USDA For. Serv. Res. Pap. PNW-22, 31 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Franklin, Jerry Forest. 1966. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. Ph. D. thesis. 132 p., illus. Wash. State Univ., Pullman.

Layser, Earle F. 1974. Vegetative classification: Its application to forestry in the northern Rocky Mountains. J. For. 72(6):354-357.

Legard, Harold A., and Leroy C. Meyer. 1973. Soil resource inventory, Willamette National Forest. USDA For. Serv. Pac. Northwest Reg., 167 p.

Peck, D. L., A. B. Grigg, H. G. Schlicker, F. G. Wells, and H. M. Dole.
1964. Geology of the central and northern parts of the western Cascade Range in Oregon. U.S. Dep. Inter. Geol. Surv. Prof. Pap. 449, 56 p.

Swanson, Frederick J., and Michael E. James.
1975. Geology and geomorphology of the H. J. Andrews Experimental Forest, western Cascades, Oregon. USDA For. Serv. Res. Pap. PNW-188, 14 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Williams, Carroll B.
1966. Snow damage to coniferous seedlings and saplings. USDA For. Serv. Res. Note PNW-40, 9 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Williams, Carroll B.
1968. Juvenile height growth of four upper-slope conifers in the Washington and northern Oregon Cascade Range. USDA For. Serv. Res. Pap. PNW-70, 13 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Williamson, R. L.
1973. Results of shelterwood harvesting of Douglas-fir in the Cascades of western Oregon. USDA For. Serv. Res. Pap. PNW-161, 13 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Zobel, D. B., W. A. McKee, G. M. Hawk, and C. T. Dyrness.
1974. Correlation of forest communities with environment and phenology on the H. J. Andrews Experimental Forest, Oregon. *In* Integrated research in the Coniferous Forest Biome, p. 48-56. R. H. Waring and R. L. Edmonds, eds. Coniferous For. Biome Bull. 5.

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GPO 986-899

Sullivan, Michael J.
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KEYWORDS: Regeneration (artificial), forest types, vegetation types, seedling growth, logging (-regeneration, Oregon (Cascade Range), *Abies amabilis*.

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